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(54) **HYDROENTANGLED FLASH SPUN WEBS HAVING CONTROLLABLE BULK AND PERMEABILITY**

WASSERSTRAHLENVERFESTIGTER SPINNVLIESTOFF MIT KONTROLLIERBAREM BAUSCH UND DURCHLÄSSIGKEIT

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**EP-A- 0 365 293** **EP-A- 0 473 325**  
**US-A- 4 190 695**

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**Description**FIELD OF THE INVENTION

5 The present invention relates to an unbonded or thermally bonded, spunlaced nonwoven fabric and a process for making the spunlaced nonwoven fabric.

BACKGROUND OF THE INVENTION

10 Spunbonded sheets of flash-spun polyolefin plexifilamentary film-fibril strands have been used in the past as disposable industrial garments. Such sheets have been made commercially by E. I. du Pont de Nemours & Company and sold under the trademark "TYVEK" spunbonded olefin. The sheets are known for their strength, durability, opacity and ability to act as a barrier to particulate matter that is sub-micron in size. Because of these desirable characteristics, the spunbonded sheets have been fashioned into many types of industrial garments, such as those worn by asbestos  
15 workers and disclosed in "Protective Apparel of Du Pont "TYVEK" - SAFETY YOU CAN WEAR", E-02145, (1987).

Although these sheets are useful in garment and apparel applications, there has been a need to add bulkiness and permeability to the sheets so that they are also useful in other specific end-use applications (e.g., as microfiltration fabrics). Although unconsolidated flash spun sheets have fairly high permeability in the unfused state, it is lost when the sheet is thermally bonded since fusing reduces permeability to a level that is unsuitable for sensitive filtration applications (e.g., vacuum cleaner bags). This is attributed to high mechanical consolidation of the microdenier, ribbon-like, high surface area fibers produced by the flash spinning process. Because of the limited ability of the flash spinning and thermal bonding process to increase permeability beyond a Gurley-Hill porosity of about 8 second/100cc, there is a significant need for a method to be developed which will increase or even maintain the permeability to a Frazier  
20 porosity of at least 1.22 m<sup>3</sup>/m<sup>2</sup>/min (4 ft<sup>3</sup>/ft<sup>2</sup>/min) following thermal bonding.

25 Various methods have been suggested in the past for providing filtration media from sheets made of flash spun plexifilaments. An example of such filtration media is commercially available from E. I. du Pont de Nemours and Company under the trademark "HYSURF" filter media. However, these methods (e.g., U.S. Patent 5,047,121 (Kochar)) require numerous process steps and equipment for cutting up and refining the flash spun sheets into pulp suitable for wet-laying on continuous papermaking machines. Only if these steps are carefully followed will subsequent thermal bonding produce a high grade paper suitable for microfiltration applications (e.g., vacuum cleaner bags).  
30

In addition, in U.S. Patent 5,023,130 (Simpson et al.) (= EP-A-0 473 325) hydroentangled flash spun polyolefin webs are disclosed having enhanced softness and barrier properties. Spunlaced fabrics made according to the Simpson et al. process are commercially available from E. I. du Pont de Nemours and Company under the trademarks "TYPRO HC" and "ComforMax 1B". These spunlaced fabrics have proven useful as inner-layer barrier liners for garments, sleeping bags, comforters and pillows. However, although these spunlaced fabrics work well with fiber insulating or filling materials, they do not work well in preventing percolation when duck feathers or down filling are used. Experience has shown that feather quills migrate through available openings in the fabric.  
35

Moreover, in U.S. Patent 4,681,801 (Eian et al.) melt-blown fiber webs are hydroentangled to force reinforcing fibers therethrough. The reinforcing fibers are hydraulically needled, preferably mechanically needled, through the melt-blown fibers and then bonded to fibers on the opposing faces of the layer of melt-blown fibers to hold the reinforcing fibers in position.  
40

EP-A-0 365 293 discloses a fabric made of lightly consolidated flash-spun polyethylene plexifilaments which is thermally embossed in order to form a point-bonded sheet that is then subjected to hydroentanglement - EP-A-0 092 819 discloses a filter medium comprising fibrous webs which are hydroentangled after or without a heat treatment.  
45

SUMMARY OF THE INVENTION

The invention as claimed in claims 1 and 3 solves the problem of how to provide a spunlaced nonwoven fabric having barrier properties and permeability in combination.  
50

Preferred embodiments are set forth in the subclaims.

In the unfused state, the spunlaced fabric has bulk and prevents percolation of feathers or down filling when used as a barrier liner in garments, pillows or the like. In addition, in the thermally bonded state, the spunlaced fabric should provide an increased level of permeability such that it is useful in sensitive microfiltration applications.

55 The unfused spunlaced fabrics are particularly well suited as inner-layer barrier fabrics such as liners for pillows, sleeping bags, comforters and disposable industrial garments (e.g., protective and medical barrier apparel). Because the pores of the unbonded flash spun web have been sufficiently closed by the penetration of stiff staple fibers into the unbonded flash spun web structure, feathers and down filling cannot percolate through the fabric itself (i.e., the fabric is downproof and featherproof). Presently, this advantage is only possible when expensive, tightly woven fabrics are

used.

The thermally bonded, spunlaced nonwoven fabrics have a Frazier porosity of at least  $1.22 \text{ m}^3/\text{m}^2/\text{min}$  ( $4 \text{ ft}^3/\text{ft}^2/\text{min}$ ), preferably  $3.05$  to  $12.2 \text{ m}^3/\text{m}^2/\text{min}$  ( $10\text{--}40 \text{ ft}^3/\text{ft}^2/\text{min}$ ), most preferably  $3.05$  to  $6.1 \text{ m}^3/\text{m}^2/\text{min}$  ( $10\text{--}20 \text{ ft}^3/\text{ft}^2/\text{min}$ ). In the prior art, thermal bonding causes spunlaced flash spun webs to suffer a significant decrease in permeability. Because the permeability of the spunlaced fabric can be increased after thermal bonding, the resulting thermally bonded spunlaced fabrics have adequate permeability for many sensitive microfiltration applications (e.g., vacuum cleaner bags) which were not possible in the past. These thermally bonded spunlaced fabrics are also believed to be useful as reinforcement construction materials. The reason for the increase in permeability is believed to be that the stiff staple fibers that are embedded into the unbonded flash spun web of step (b) of claim 3 reduce mechanical consolidation and that the flash spun fibers shrink causing permeability to increase directly with the thermal bonding temperature.

A further advantage of the thermally bonded, spunlaced nonwoven fabric is that the side of the fabric from which the staple fibers penetrate the unbonded flash spun web provide a gradient, depth-type filter that prevents blinding of the microfiber portion of the fabric when in use.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood with reference to the following figures:

Fig. 1 is a schematic side view of an apparatus for continuously forming a composite web structure from staple fibers and an unbonded flash spun web and hydraulically needling the composite web structure to form spunlaced nonwoven fabrics in accordance with the invention.

Fig. 2 is a modified version of Fig. 1 showing belt water jets in addition to drum water jets.

Fig. 3 is a schematic view of a palmer bonder used to optionally thermally bond the spunlaced nonwoven fabric of Figs. 1 or 2.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One of the starting materials for the process of the present invention is a lightly consolidated or unconsolidated flash-spun polyolefin, preferably polyethylene or polypropylene, plexifilamentary film-fibril web produced by the general procedure of Steuber, U.S. Patent 3,169,899, the entire contents of which are incorporated herein by reference. According to the preferred method for making the starting sheets, a linear polyethylene having a density of  $0.96 \text{ g/cm}^3$ , a melt index of 0.9 (determined by ASTM method D-1238-57T, condition E) and a  $135^\circ\text{C}$  upper limit of its melting temperature range is flash spun from a 12 weight percent solution of the polyethylene in trichlorofluoromethane. The solution is continuously pumped to spinneret assemblies at a temperature of about  $179^\circ\text{C}$  and a pressure above about  $8.5 \text{ MPa}$  (85 atmospheres). The solution is passed in each spinneret assembly through a first orifice to a pressure let-down zone and then through a second orifice into the surrounding atmosphere. The resulting film fibril strand (i.e., plexifilament) is spread and oscillated by means of a shaped rotating baffle, electrostatically charged, and then is deposited on a moving collection belt. The spinnerets are spaced to provide overlapping, intersecting deposits on the belt to form a wide, flash spun nonwoven web. The web may then be lightly consolidated by passage through a nip that applies a load of about  $17.6 \text{ N}$  (1.8 kilograms) per cm of web width or it may remain unconsolidated. Generally, webs having a basis weight in the range of  $34$  to  $119 \text{ g/m}^2$  ( $1.0$  to  $3.5 \text{ oz/yd}^2$ ) are suitable for use in the process of the present invention. Also, webs having a strand diameter of between  $1\text{--}10$  microns are preferred. The web is not thermally bonded or fused (i.e., unbonded) prior to hydraulic needling treatment, the description of which follows hereinafter.

The other starting material is a web of staple fibers. The web may be prepared according to the teachings of U.S. Patent 3,485,706 (Evans), the entire contents of which are incorporated herein by reference. Preferably, the web of staple fibers should be carded or air-laid such that it can easily be positioned against the unbonded flash spun web and supported on a screen (e.g., a 75 mesh screen).

As used herein, "staple fibers" means any relatively stiff staple length fiber that is typically used in the art of hydraulic needling. The fiber must have adequate modulus (i.e., not too high and not too low) to be embedded and entangled with the unbonded flash spun web. The staple fibers can be made of synthetic or natural fibers or blends of both. They may be single component as well as bicomponent staple fibers. Non-limiting examples of suitable staple fibers include those made of woodpulp, polyester, nylon, acrylics and aramids such as "KEVLAR" and "NOMEX".

As used herein, the terms "unfused" or "unbonded" mean that the web or fabric has not been thermally bonded or thermally fused. This is to be distinguished from mechanical bonding (e.g., hydraulic needling or light consolidation).

In use, the web of staple fibers is positioned against an unbonded flash spun web on a supporting screen to form a composite web structure. The basis weight ratio of the staple fiber web to the unbonded flash spun web can be varied depending on the end-use desired. For example, if increased bulkiness is desired, increased amounts of staple fibers are used. The supported composite web structure is then passed under a series of high pressure water jets (preferably from  $1.38$  to  $20.1 \text{ MPa}$  ( $200$  to  $3,000 \text{ psi}$ ) jet pressure) such that the staple fibers are forced (i.e., hydraulically needed)

into the unbonded flash spun web. The staple fibers penetrate the flash spun web such that they embed and entangle with the flash spun web and form a spunlaced nonwoven fabric. Methods and equipment suitable for hydraulically needling the composite web structure are disclosed in more detail in the Evans patent and in U.S. Patent 3,403,862 (Dworjanyan). Typically, after the composite web structure is hydraulically needled into a spunlaced nonwoven fabric excess water is removed by vacuum dewatering and/or by squeeze rolls. (Squeeze rolling is a compaction force which causes the spunlaced nonwoven fabric to decrease in permeability). Drying is then performed at a temperature which doesn't cause thermal bonding (i.e., fusing) of the fabric to take place.

Following hydraulic needling, the unbonded, spunlaced nonwoven fabric has added thickness and a Frazier porosity of at least  $1.22 \text{ m}^3/\text{m}^2/\text{min}$  ( $4 \text{ ft}^3/\text{ft}^2/\text{min}$ ). The fabric is useful as a bulky, inner-layer barrier fabric for garments, sleeping bags, pillows, comforters and the like. It is also useful as a medical barrier fabric and as a protective apparel. Because the pores of the unbonded flash spun web have been sufficiently blocked by the stiff staple fibers (i.e., increased barrier properties), the resulting spunlaced nonwoven fabric has surprisingly proven to prevent percolation when used with down filling or natural feathers (i.e., quills are prevented from migrating through the fabric).

Optionally, if sensitive filtration or other applications are desired, the spunlaced nonwoven fabric may be thermally bonded. In the past, thermal bonding always caused the permeability of a flash spun web to significantly decrease, just the opposite of what is wanted for microfiltration end-uses. However, to the applicants surprise, thermal bonding actually allows the permeability to be maintained and more importantly increased. In fact, depending on the level of thermal bonding used, the permeability of the spunlaced nonwoven fabric can be tailored for the desired end-use (this is typically between about  $3.05$  and  $12.2 \text{ m}^3/\text{m}^2/\text{min}$  ( $10$  and  $40 \text{ ft}^3/\text{ft}^2/\text{min}$ )). This phenomenon is believed to be caused by fiber shrinkage of the flash spun web and because the staple fibers reduce compaction of the flash spun fibers onto themselves during thermal bonding. (Thermal bonding allows fiber shrinkage forces to dominate compaction forces (e.g., squeeze roller compaction)). As a result, the greater the thermal bonding level (i.e., higher the thermal bonding temperature and/or pressure) the greater the permeability is increased. If too low a thermal bonding temperature/pressure is used (i.e., below about  $135^\circ \text{C}$  and  $331 \text{ kPa}$  ( $48 \text{ psi}$ )), the permeability will actually be decreased since the compaction forces are greater than resulting fiber shrinkage. Because permeability can be controlled, the resulting thermally bonded, spunlaced nonwoven fabrics typically have a lower pressure drop than synthetic fabrics made on conventional wet-lay papermaking machines (e.g., the high grade polyethylene paper of U.S. Patent 5,047,121 (Kochar)).

It has also been found that varying the amount of water jet energy applied during hydraulic needling treatment will affect the depth of staple fiber penetration into the unbonded flash spun web and ultimately the ability of the spunlaced nonwoven fabric's permeability to be increased after thermal bonding. Although even a slight degree of staple fiber penetration will prevent quills from percolating through the resulting unbonded, spunlaced nonwoven fabric when used in barrier liner applications, the depth of penetration is important for high permeability filtration applications. It has been determined that slight penetration of the staple fibers will allow the permeability to be increased only slightly after thermal bonding. However, very deep penetration of the staple fibers will allow permeability to be increased to a large extent after thermal bonding. Therefore, in addition to the thermal bonding level used, the amount of water jet energy employed during hydraulic needling can be varied (see Figs. 1 and 2 below) to tailor the ultimate permeability of the thermally bonded, spunlaced nonwoven fabric.

Referring now to the figures, schematic diagrams are shown to illustrate typical hydraulic needling methods and equipment (Figs. 1 and 2) as well as suitable thermal bonding equipment (Fig. 3).

Fig. 1 illustrates an apparatus for continuous processing of the staple fiber web/unbonded flash spun web composite structure to convert it into a spunlaced nonwoven fabric. In particular, staple fibers 1 are doffed in an air stream 2 onto a conveyor 3 where it is lightly needled by a few consolidating water jets 4 to tack it down. The staple fiber web is then positioned against an unbonded flash spun web 5 on conveyor 6 to form a composite web structure 7. The composite web structure is then drawn around drum washer 8 where a series of drum water jets 9 hydraulically needle the staple fiber web into the unbonded flash spun web such that the staple fibers are embedded into and entangled with the unbonded flash spun web to form a spunlaced nonwoven fabric 10. Thereafter, excess water is removed from the spunlaced nonwoven fabric by squeeze rolls 11 and vacuum dewatering equipment 12. The dewatered spunlaced nonwoven fabric 13 is then dried and collected on a wind up roll (not shown) for transporting or storage.

Fig. 2 is the same as Fig. 1 except that a series of water jets 14 are also used to hydraulically needle the unbonded flash spun web side of the composite web structure on conveyor 6. In this manner, both sides of the composite web structure are struck by high pressure water jets during the treatment process.

Fig. 3 illustrates a palmer roll bonder which is optionally used on the unbonded, spunlaced nonwoven fabric 13 of Figs. 1 or 2. (It will be understood that other bonding techniques or equipment may be appropriately used and that using a palmer roll bonder is not critical to the invention). If the unbonded, spunlaced nonwoven fabric 13 is to be thermally bonded, it is unwound and fed to a palmer bonder 19 where it is wrapped around a 60 inch diameter heated drum 21 by conveyor blanket 22. Conveyor blanket 22 also helps to reduce shrinkage by applying pressure to the fabric as it is thermally bonded. Drum 21 thermally bonds the fabric by being heated to a temperature above the fusing

point of the strands making up the flash spun web. Thereafter, the fabric is wrapped around a 24 inch chilled roll 23 to cool the fabric after thermal bonding. This is to prevent fabric shrinkage and edge curling. Thereafter, the thermally bonded, spunlaced nonwoven fabric 24 is collected on a wind up roll (not shown) for transporting or storage.

## 5 EXAMPLES

In the non-limiting Examples which follow, the following test methods were employed to determine various reported characteristics and properties. ASTM refers to the American Society of Testing Materials. TAPPI refers to the Technical Association of the Pulp and Paper Industry.

10 Basis weight was determined by ASTM D-3776-85 and is reported in 34 g/m<sup>2</sup> (oz/yd<sup>2</sup>). Strip tensile strength was determined by ASTM D 1117 and is reported in 175.1 N/m (lbs/linear inch). Frazier porosity was determined by ASTM D737-75 and is reported in 0.301 m<sup>3</sup>/m<sup>2</sup>/min (ft<sup>3</sup>/ft<sup>2</sup>/min). Opacity was determined by TAPPI T-245 M-60 and is reported as a percentage.

Gurley Hill Porosity was determined by ASTM D-726-84 and is reported in second/100 cc.

15 Pore size was determined using a Coulter Porometer commercially available from Coulter Electronics Limited, Luton Beds., England. The sample to be analyzed was thoroughly wetted so that all accessible pores were completely filled with liquid. The wetted sample was then placed in the sample body of the filter holder assembly, secured with a locking ring and the pore size value was recorded. Values are reported in microns for the maximum, minimum and mena pore size distribution.

20 Surface Area (SA) was determined by using a Strohlein instrument which measures a 3 gram sample for single point BET nitrogen absorption. It is reported in m<sup>2</sup>/g.

Mullen Burst was determined by TAPPI T403-85 and is reported in psi.

### Example 1

25 In this example, several samples were made by the inventive process using different sets of conditions. In all samples, 2 consolidation jets were used to tack down loose fibers.

In sample 1, a pre-formed scrim of hydroentangled staple fibers was hydraulically needed into an unbonded T-800 "TYVEK" web using only belt washer jets (drum washer jets were turned off). Thus, this sample was prepared without loose staple fibers. The squeeze rolls were left open.

30 In sample 2, a staple fiber web was hydraulically needed into an unbonded T-800 "TYVEK" web using a series of drum washer jets but no belt washer jets. In this sample, 5 jets (5/20, 5/20, 5/40, 5/40, 5/40 jets) were used at 2500, 2300, 2000, 2100 and 2000 psi respectively. The squeeze rolls were left open.

In sample 3, the same conditions were followed as in sample 2 except that the squeeze rolls were closed.

35 In sample 4, the same conditions were followed as in sample 2 except that the type of water jets were altered. In this sample, 6 jets (5/20, 7/10, 5/20, 5/40, 5/40 and 5/40 jets) were used at 2500, 0, 2500, 2450, 2400 and 2500 psi respectively. The squeeze rolls were left open.

In sample 5, the sample conditions were followed as in sample 2 except that the type of water jets were altered. In this sample, 2 jets (5/20 and 5/40 jets) were used at 8.274 and 10.34 MPa (1200 and 1500 psi) respectively. The squeeze rolls were closed.

40 The samples were tested for various physical properties while unbonded (U) and after thermal bonding (B) at 400 kPa (58 psi) at 30.5 m/min (100 ft/min) in a palmer roll bonder.

TABLE 1

|                              | U    | B    | U    | B    | U    | B    | U    | B    | U    | B    |
|------------------------------|------|------|------|------|------|------|------|------|------|------|
| Sample                       | 1    |      | 2    |      | 3    |      | 4    |      | 5    |      |
| Basis Weight                 | 2.6  | 2.8  | 2.8  | 3.2  | 2.7  | 3.0  | 2.6  | 2.8  | 2.3  | 2.5  |
| Thickness (0.0254 mm (mils)) | 18.8 | 13.7 | 20.6 | 13.6 | 12.0 | 12.5 | 19.9 | 13.2 | 10.4 | 11.2 |
| Frazier Porosity             | 12.6 | 8.5  | 11.3 | 17.7 | 2.1  | 14.6 | 12.2 | 15.2 | 0.9  | 4.1  |
| Opacity                      | 95.7 | 76.6 | 93.5 | 85.9 | 93.8 | 75.9 | 92.1 | 80.7 | 96.9 | 78.8 |

55 Table 1 demonstrates that the Frazier porosity unexpectedly increases during thermal bonding of samples 2-4 where the staple fibers are deeply embedded in the unbonded T-800 "TYVEK" web whereas the pores of the unbonded T-800 "TYVEK" web close up during thermal bonding of sample 1 (i.e., Frazier porosity decreases) where the less mobile fibers of the pre-formed scrim penetrate only the surface layers of the unbonded T-800 "TYVEK" web. Sample 5 demonstrates that Frazier porosity can be controlled (i.e., tailored) by varying the amount of water jet energy during

hydraulic needling. In this case, lower water jet energy causes less penetration of staple fibers into the unbonded T-800 "TYVEK" web and a smaller increase in Frazier porosity following thermal bonding.

In addition, sample 3 shows that even if the spunlaced fabric is consolidated (i.e., squeeze rolls closed) such that a low Frazier porosity exists in the unbonded state, the Frazier porosity can still be significantly increased with adequate thermal bonding.

## Example 2

In this example, the inventive process was followed with the following modifications. Eight (8) spunlaced fabric samples were made from unbonded T-800 "TYVEK" and staple fibers using various staple fiber types and weights. They were as follows:

Sample A = 30.5 g/m<sup>2</sup> (9 oz/yd<sup>2</sup>) 1.5 dtex per filament (1.35 dpf) polyester fiber/53 g/m<sup>2</sup> (1.56 oz/yd<sup>2</sup>) T-800 "TYVEK" web

Sample B = 30.5 g/m<sup>2</sup> (0.9 oz/yd<sup>2</sup>) splittable ribbon X-section acrylic fiber/53 g/m<sup>2</sup> (1.56 oz/yd<sup>2</sup>) T-800 "TYVEK" web

Sample C = 28.8 g/m<sup>2</sup> (0.85 oz/yd<sup>2</sup>) splittable polyester fiber/53 g/m<sup>2</sup> (1.56 oz/yd<sup>2</sup>) T-800 "TYVEK" web

Sample D = 30.5 g/m<sup>2</sup> (0.9 oz/yd<sup>2</sup>) 2.78 dtex per filament (2.5 dpf) ribbon X-section polyester fiber/53 g/m<sup>2</sup> (1.56 oz/yd<sup>2</sup>) T-800 "TYVEK" web

Sample E = 47.5 g/m<sup>2</sup> (1.4 oz/yd<sup>2</sup>) 3.33 dtex per filament (3 dpf) polyester fiber/53 g/m<sup>2</sup> (1.56 oz/yd<sup>2</sup>) T-800 "TYVEK" web

Sample F = 74.6 g/m<sup>2</sup> (2.2 oz/yd<sup>2</sup>) 6.67 dtex per filament (6 dpf) bicomponent (side-by-side) polyester fiber/53 g/m<sup>2</sup> (1.56 oz/yd<sup>2</sup>) T-800 "TYVEK" web

Sample G = 67.8 g/m<sup>2</sup> (2.0 oz/yd<sup>2</sup>) 1.5 dtex per filament (1.35 dpf) polyester fiber/53 g/m<sup>2</sup> (1.56 oz/yd<sup>2</sup>) T-800 "TYVEK" web

Sample H = 34 g/m<sup>2</sup> (1.0 oz/yd<sup>2</sup>) wetlaid woodpulp (60 wt.%) and 1.67 dtex per filament (1.5 dpf) polyester (40 wt.%) /53 g/m<sup>2</sup> (1.56 oz/yd<sup>2</sup>) T-800 "TYVEK" web

Samples C & D contain fibers that split during hydroentangling. Denier per filament of the split fibers range from 0.22 to 2.78 dtex per filament (0.2 to 2.5 dpf).

In Table 2, physical properties are reported for unbonded, spunlaced nonwoven fabrics according to the invention.

TABLE 2

| Sample           | A     | B     | C     | D     | E     | F     | G     | H     |
|------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Basis Weight     | 2.71  | 2.51  | 4.32  | 2.47  | 2.86  | 3.74  | 3.89  | 2.77  |
| Thickness (mils) | 20.20 | 20.57 | 17.13 | 20.75 | 21.49 | 29.09 | 30.52 | 21.91 |
| Frazier Porosity | 10.93 | 10.09 | 9.54  | 13.98 | 14.63 | 10.12 | 9.85  | 11.35 |
| Opacity          | 93.88 | 94.67 | 95.82 | 93.93 | 94.91 | 95.75 | 96.02 | 95.72 |
| Surface Area     | 6.79  | 6.90  | 6.34  | 4.94  | -     | 4.91  | 4.78  | 6.85  |

Table 3 shows the physical properties of samples A-H after they have been thermally bonded using 400 kPa (58 psi) steam at a speed of 30.5 m/min (100 ft/min)(i.e., thermally bonded, spunlaced nonwoven fabrics).

TABLE 3

| Sample                       | A     | B     | C     | D     | E     | F     | G     | H     |
|------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Basis Weight                 | 2.80  | 2.48  | 2.26  | 2.66  | 3.05  | 3.90  | 4.19  | 2.72  |
| Thickness (0.0254 mm (mils)) | 16.44 | 14.60 | 12.93 | 15.81 | 19.53 | 22.59 | 23.98 | 23.11 |
| Frazier Porosity             | 18.65 | 14.98 | 10.84 | 19.48 | 19.07 | 19.77 | 12.98 | 12.73 |
| Opacity                      | 84.15 | 85.52 | 86.32 | 89.00 | 87.10 | 85.42 | 90.76 | 93.07 |
| Pore Size Dist.(MIN)         | 7.1   | 6.5   | 6.5   | 7.6   | 8.0   | 6.7   | 6.7   | 6.4   |
| Pore Size Dist.(MAX)         | 35.0  | 32.5  | 31.1  | 43.5  | 47.8  | 37.2  | 29.7  | 31.5  |
| Pore Size Dist.(MEAN)        | 11.5  | 10.7  | 10.0  | 11.3  | 13.4  | 11.2  | 10.9  | 10.0  |

Comparing Tables 2 and 3 demonstrates that thermal bonding can be used to tailor the Frazier porosity (i.e., maintain or increase) of the spunlaced fabric to a level well suited for filtration applications such as vacuum cleaner bags (i.e., 3.05-6.1 m<sup>3</sup>/m<sup>2</sup>/min (10-20 ft<sup>3</sup>/ft<sup>2</sup>/min)).

**Example 3**

In this example, the effect of the level of thermal bonding is demonstrated. Samples 1-4 from Example 1 were thermally bonded at (1) 331 kPa (48 psi) steam pressure at 30.5 m/min (100 ft/min) and (2) 372 kPa (54 psi) steam pressure at 30.5 m/min (100 ft/min). The physical properties of the resulting thermally bonded, spunlaced nonwoven fabrics are set forth in Table 4 below.

TABLE 4

|                                 | 331 kPa<br>(48 psi) | 372 kPa<br>(54 psi) | 331 kPa<br>(48 psi) | 372 kPa<br>(54 psi) | 331 kPa<br>(48 psi) | 372 kPa<br>(54 psi) | 331 kPa<br>(48 psi) | 372 kPa<br>(54 psi) |
|---------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Sample                          | 1                   |                     | 2                   |                     | 3                   |                     | 4                   |                     |
| Basis Weight                    | 2.9                 | --                  | 3.0                 | 2.9                 | 2.7                 | 2.8                 | 2.8                 | 2.6                 |
| Thickness<br>(0.0254 mm (mils)) | 15.4                | --                  | 14.6                | 13.8                | 13.3                | 12.8                | 16.1                | 14.7                |
| Frazier Porosity                | 10.7                | --                  | 9.2                 | 11.3                | 5.5                 | 11.6                | 9.8                 | 12.5                |
| Opacity                         | 94.3                | --                  | 92.9                | 88.1                | 91.3                | 84.1                | 94.1                | 89.8                |

When compared with Table 1 for physical properties while unbonded and at 58 psi steam pressure at 0.305 m/min (100 ft/min), it is clear that increasing the bonding level (i.e., temperature) will increase the Frazier porosity of the resulting thermally bonded, spunlaced nonwoven fabric according to the invention (samples 1-5).

Table 5 compares physical properties of a representative thermally bonded sample of the invention (sample A) with ranges of typical physical properties for samples of commercially available prior art filtration media.

TABLE 5

|                        | Sample A | "HYSURF" | MELT-BLOWN | "TYVEK" | Paper Vacuum Cleaner Bag |
|------------------------|----------|----------|------------|---------|--------------------------|
| Frazier Porosity       | 18.7     | 8-18     | 30-40      | <0.1    | 24                       |
| Pore Size Dist. (MIN)  | 7.1      | 5-7      | 8-9        | 3       | 10                       |
| Pore Size Dist. (MAX)  | 35.0     | 19-23    | 30-40      | 9-12    | 69                       |
| Pore Size Dist. (MEAN) | 11.5     | 9-12     | 14-17      | 4-6     | 19                       |
| Mullen Burst           | 91.8     | 40       | 10-15      | 90-120  | 30                       |

This comparative table illustrates the ability of the inventive sample to act as a suitable filtration media for such things as vacuum cleaner bags.

**Claims**

1. An unbonded or thermally bonded, spunlaced nonwoven fabric (13; 24) comprised of an unbonded flash spun web which is comprised of plexifilaments of polyolefin or polyethylene or polypropylene (5) having staple fibers (1) embedded into and entangled therewith, the fabric having a Frazier porosity of at least 1.22 m<sup>3</sup>/m<sup>2</sup>/min (4 ft<sup>3</sup>/ft<sup>2</sup>/min).
2. The thermally bonded, spunlaced nonwoven fabric (24) of claim 1 wherein the fabric has a Frazier porosity of between 3.05 and 12.2 m<sup>3</sup>/m<sup>2</sup>/min (10 and 40 ft<sup>3</sup>/ft<sup>2</sup>/min).
3. A process for making the spunlaced nonwoven fabric (13; 24) of claims 1 or 2 comprising the steps of:
  - (a) positioning a web of staple fibers (1) against an unbonded flash spun web (5), which is comprised of plexifilaments of polyolefin or polyethylene or polypropylene on a supporting screen (6, 8) to form a composite web structure (7); and
  - (b) hydraulically needling the staple fiber side of the supported composite web structure (7) using water jets (9) operating at a pressure of between 1340 and 20,700 kN (200 and 3,000 psi) such that the staple fibers

penetrate the flash spun web (5) and are embedded into and entangled with the unbonded flash spun web.

4. The process according to claim 3 wherein the staple fibers comprise polyester, nylon, acrylics, aramids, woodpulp or mixtures thereof.
5. The process of claims 3 or 4 further comprising the step of thermally bonding the spunlaced nonwoven fabric (13) to maintain or increase the permeability of the fabric.
6. The process of claim 5 wherein the fabric has a Frazier porosity of between 3.05 and 12.2 m<sup>3</sup>/m<sup>2</sup>/min (10 and 40 ft<sup>3</sup>/ft<sup>2</sup>/min).
7. A downproof and featherproof liner made from the unbonded, spunlaced nonwoven fabric (13) of claim 1.
8. The unbonded, spunlaced nonwoven fabric of claim 1 wherein the fabric is used as a liner for pillows, sleeping bags, comforters or garments.
9. A filtration media made from the thermally bonded, spunlaced nonwoven fabric (24) of claim 2.
10. A vacuum cleaner bag made from the thermally bonded, spunlaced nonwoven fabric (24) of claim 2.

#### Patentansprüche

1. Ungebundener oder durch Wärme gebundener Spunlaced-Faservliesstoff (13; 24) umfassend eine ungebundene flashgesponnene Bahn (5), enthaltend Plexifilamente aus Polyolefin in Form von Polyethylen oder Polypropylen, in welche Bahn Stapelfasern (1) eingebettet und mit dieser verschlungen sind, wobei der Stoff eine Frazier-Porosität von mindestens 1,22 m<sup>3</sup>/m<sup>2</sup>/min (4 ft<sup>3</sup>/ft<sup>2</sup>/min) aufweist.
2. Durch Wärme gebundener Spunlaced-Faservliesstoff (24) nach Anspruch 1, wobei der Stoff eine Frazier-Porosität zwischen 3,05 und 12,2 m<sup>3</sup>/m<sup>2</sup>/min (10 und 40 ft<sup>3</sup>/ft<sup>2</sup>/min) aufweist.
3. Verfahren zur Herstellung des Spunlaced-Faservliesstoffs (13; 24) der Ansprüche 1 oder 2, umfassend die folgenden Schritte:
  - (a) Positionieren einer Bahn von Stapelfasern (1) gegen eine ungebundene, flashgesponnene Bahn (5), bestehend aus Plexifilamenten von Polyolefin in Form von Polyethylen oder Polypropylen auf einem Haltesieb (6, 8), um eine Verbundbahnstruktur (7) zu bilden; und
  - (b) Wasserdruckvernadeln der Stapelfaserseite der gehaltenen Verbundbahnstruktur (7) mit Hilfe von Wasserstrahldüsen (9), die bei einem Druck zwischen 1340 und 20700 kN (200 und 3000 psi) arbeiten, so daß die Stapelfasern in die flashgesponnene Bahn (5) eindringen und in die ungebundene, flashgesponnene Bahn eingebettet und mit dieser verschlungen werden.
4. Verfahren nach Anspruch 3, bei dem die Stapelfasern Polyester, Nylon, Acryle, Aramide, Holzschliff oder Mischungen derselben umfassen.
5. Verfahren nach den Ansprüchen 3 oder 4, des weiteren umfassend den Schritt des Wärmebindens des Spunlaced-Faservliesstoffs (13), um die Durchlässigkeit des Stoffs aufrechtzuerhalten oder zu erhöhen.
6. Verfahren nach Anspruch 5, bei dem der Stoff eine Frazier-Porosität zwischen 3,05 und 12,2 m<sup>3</sup>/m<sup>2</sup>/min (10 und 40 ft<sup>3</sup>/ft<sup>2</sup>/min) aufweist.
7. Daunenfester und federfester Futterstoff, hergestellt aus dem ungebundenen, flashgesponnenen Faservliesstoff (13) von Anspruch 1.
8. Ungebundener Spunlaced-Faservliesstoff nach Anspruch 1, wobei der Stoff als Futterstoff für Kissen, Schlafsäcke, Steppdecken oder Kleidungsstücke verwendet wird.
9. Filtermedium, hergestellt aus dem wärmegebundenen Spunlaced-Faservliesstoff (24) von Anspruch 2.



10. Staubsaugerbeutel, hergestellt aus dem wärmegebundenen Spunlaced-Faservliesstoff (24) von Anspruch 2.

# Revendications

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1. Un tissu non tissé entrelacé, non lié ou thermiquement lié (13; 24) comprenant une bande filée flash non liée qui comprend des plexifilaments de polyoléfine, de polyéthylène ou de polypropylène (5) comportant des brins coupés (1) noyés dans et entremêlés avec le tissu présentant une porosité Frazier d'au moins  $1,22 \text{ m}^3/\text{m}^2/\text{min}$  ( $4 \text{ pied}^3/\text{pied}^2/\text{min}$ ).

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2. Le tissu non tissé entrelacé lié thermiquement (24) selon la revendication 1 dans lequel le tissu présente une porosité Frazier comprise entre  $3,05$  et  $12,2 \text{ m}^3/\text{m}^2/\text{min}$  ( $10$  à  $40 \text{ pied}^3/\text{pied}^2/\text{min}$ ).

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3. Un procédé de fabrication de tissu non tissé entrelacé (13; 24) selon l'une quelconque des revendications 1 ou 2 comprenant les étapes de:

a) positionnement d'une bande de brins coupés (1) contre une bande filée flash non liée (5) comprenant des plexifilaments de polyoléfine de polyéthylène ou de polypropylène sur un tamis de support (6; 8) pour former une structure de bande composite (7) et

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b) piqûre hydraulique de la face de fibres coupées de la structure de bande composite (7) en utilisant des jets d'eau (9) en opérant à une pression comprise entre  $1340$  et  $20700 \text{ kN}$  ( $200$  et  $3000 \text{ psi}$ ) de façon que les fibres coupées pénètrent dans la bande filée flash (5) et soient noyées dans et entremêlées avec la bande filée flash non liée.

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4. Le procédé selon la revendication 3 dans lequel les brins coupés comprennent du polyester, du nylon, des acryliques, des aramides, de la pulpe de bois ou leurs mélanges.

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5. Le procédé selon la revendication 3 ou 4 comprenant en outre les étapes de liaison thermique du tissu non tissé entrelacé (13) pour conserver ou augmenter la perméabilité du tissu.

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6. Le procédé selon la revendication 5 dans lequel le tissu présente une porosité Frazier comprise entre  $3,05$  et  $12,2 \text{ m}^3/\text{m}^2/\text{min}$  ( $10$  et  $40 \text{ pied}^3/\text{pied}^2/\text{min}$ ).

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7. Une doublure de clos pour duvet et plumes fabriquée en tissu non tissé entrelacé et non lié (13) selon la revendication 1.

8. Le tissu non tissé entrelacé non lié selon la revendication 1 dans lequel le tissu est utilisé en tant que doublure d'oreiller, de sac de couchage, de courteline, ou de vêtement.

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9. Un moyen de filtration fabriqué en tissu non tissé entrelacé et thermiquement lié (24) selon la revendication 2.

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10. Un sac d'aspirateur fabriqué en tissu non tissé entrelacé thermiquement lié (24) selon la revendication 2.

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FIG.1

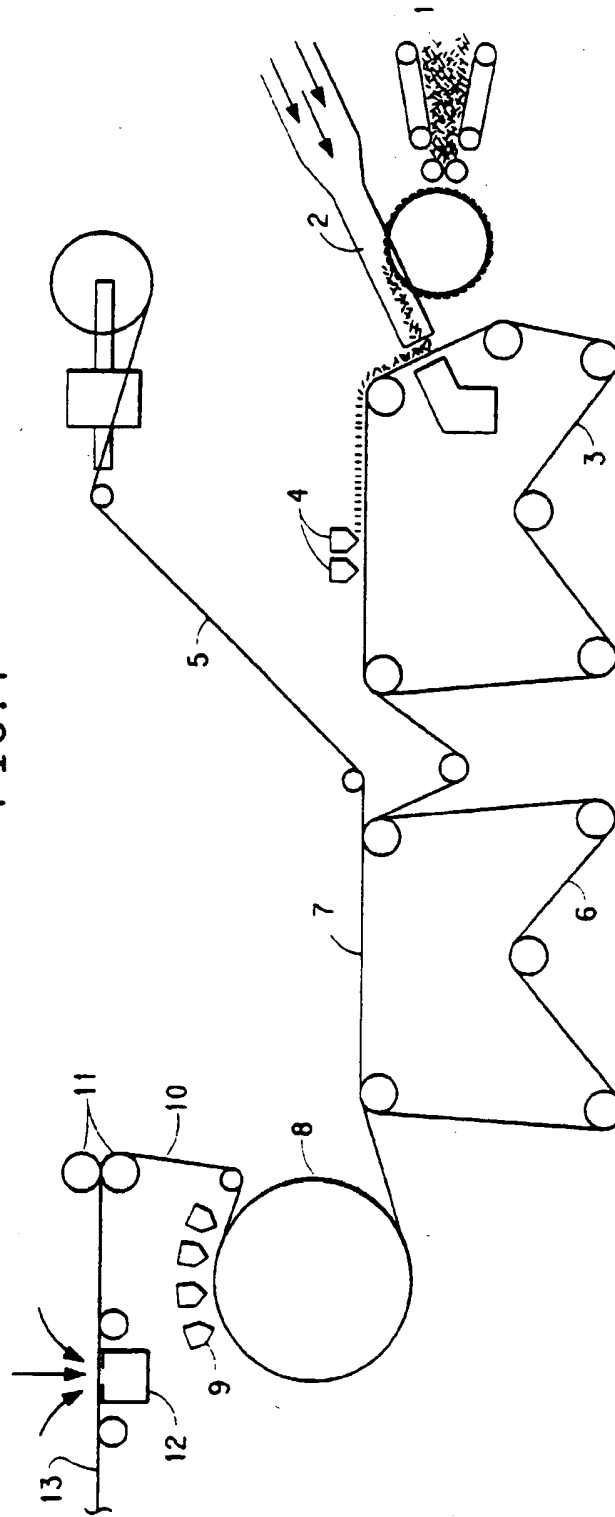


FIG.2

